Lake Atitlán, Guatemala: challenges in management and collaboration stimulated by ecological changes

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- Amber Roegner, Tina Hammel, Bob Richards- UC Davis
- Jessica Corman, Jim Elser- Arizona State University
- 60+ student classes from 2010, 2012
- Amigos del Lago

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Universidad del Valle de Guatemala

Unidos por un Lago Atitlán Vivo

Universidad Rafael Landívar

The University of California Davis

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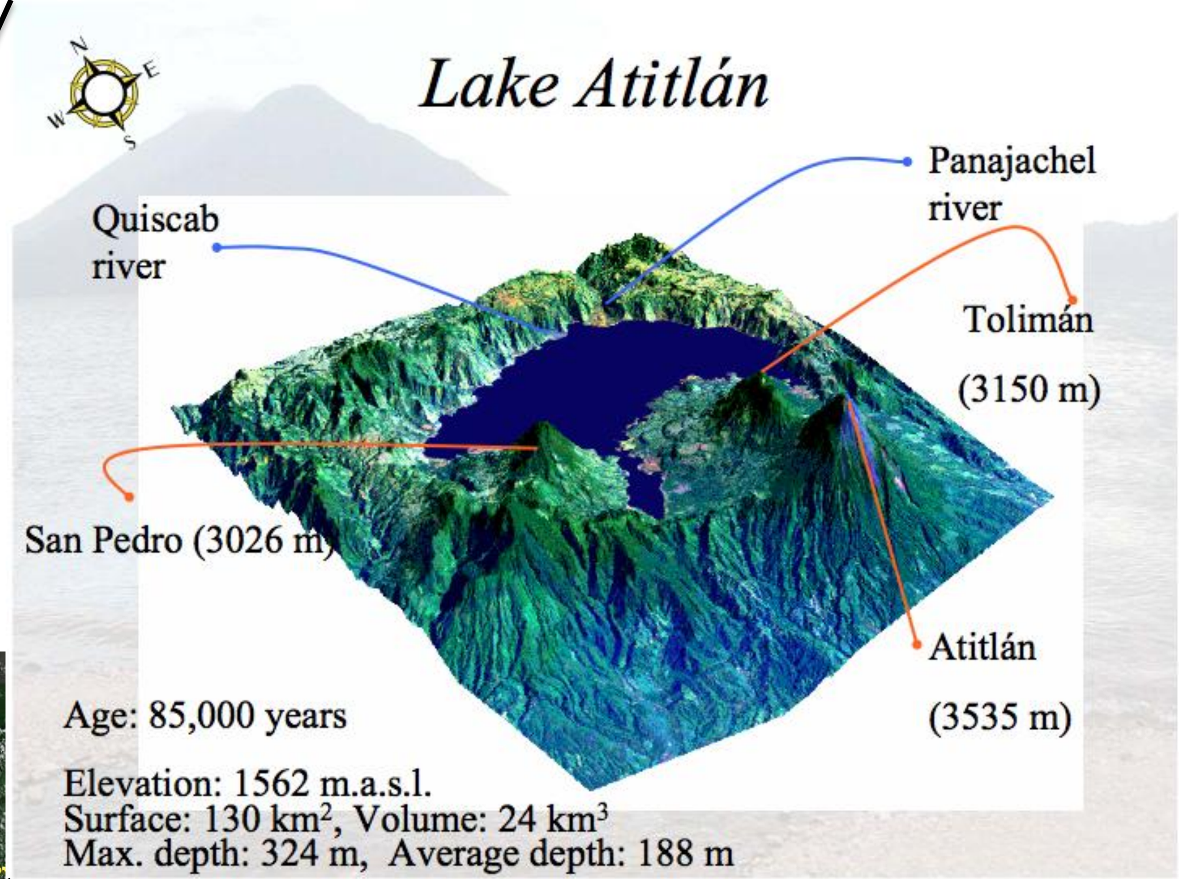
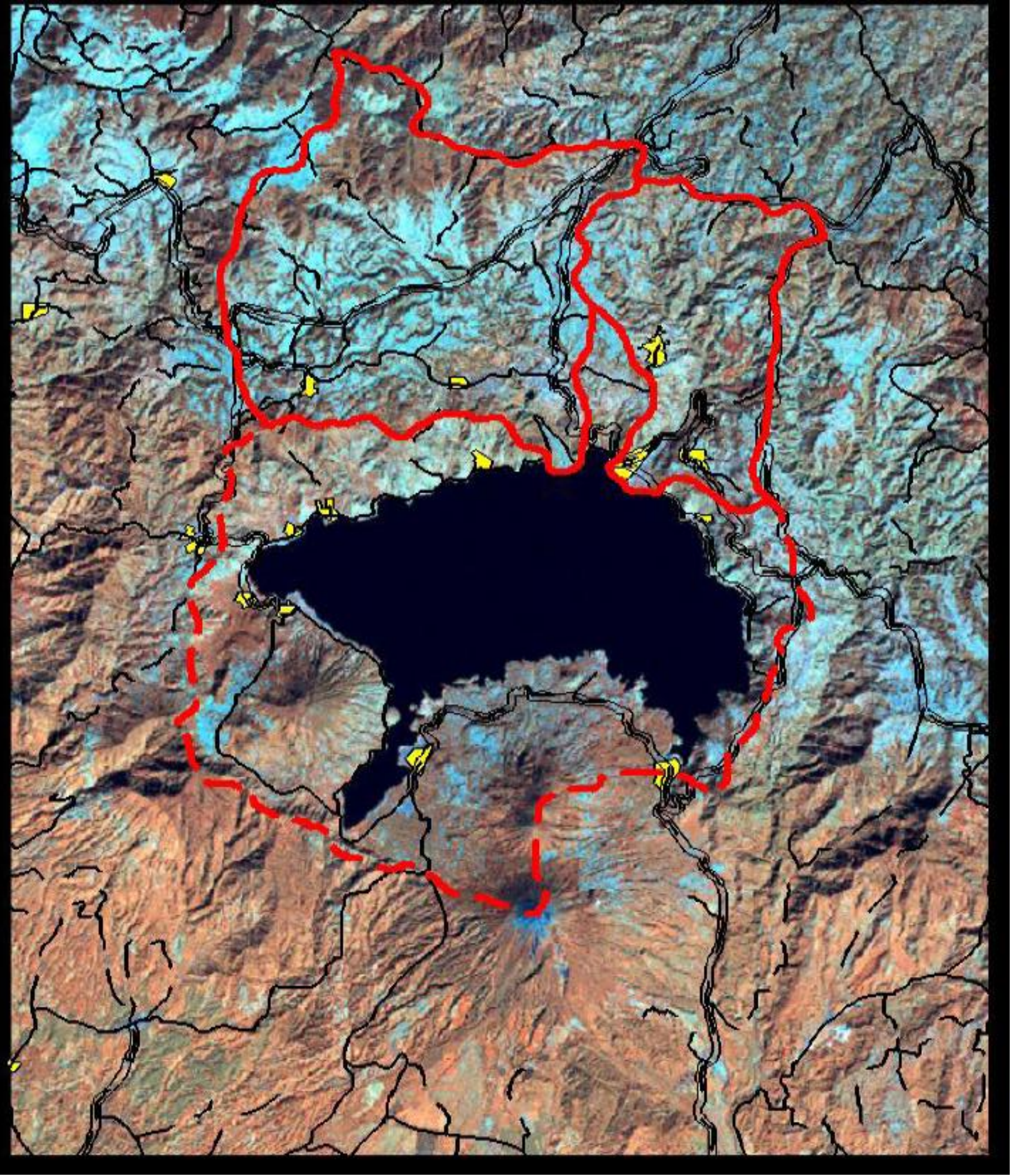
Volcanic, terminal lake described by Deevey & others as oligotrophic





Watershed area: 541 km^2
Lake surface: 130 km^2
Elevataion: 5100 ft
z= 320 m

Endorheic : without an obvious outflow, seepage is important but areas no identified, detailed bathymetric map lacking

Two principal rivers: Quiscab and San Francisco

Long residence time: 80 to 120 years?

Inhabitants: +400,000 (200,000 in 2002), 15 Municipalities, 3 Departments

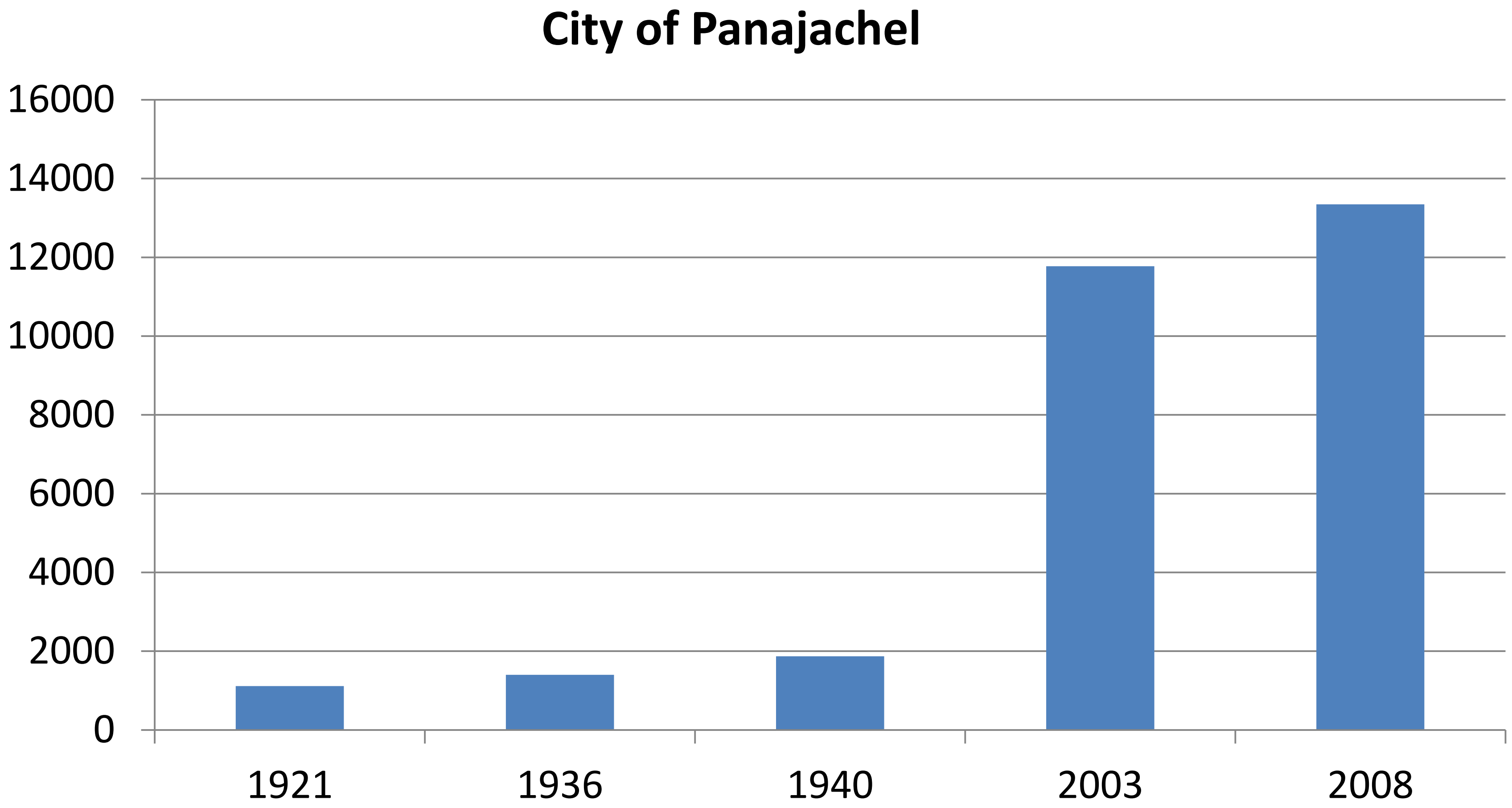
Population density: 498/ km^2 33% urban

Cultures: Kaqchikel, Tzutijil, Kékchi,non indígenous and non-Guatemalan

Económic Activities: Agriculture, Tourism, Crafts, Fishing

Human impact: 3,000 years

Accelerated population growth

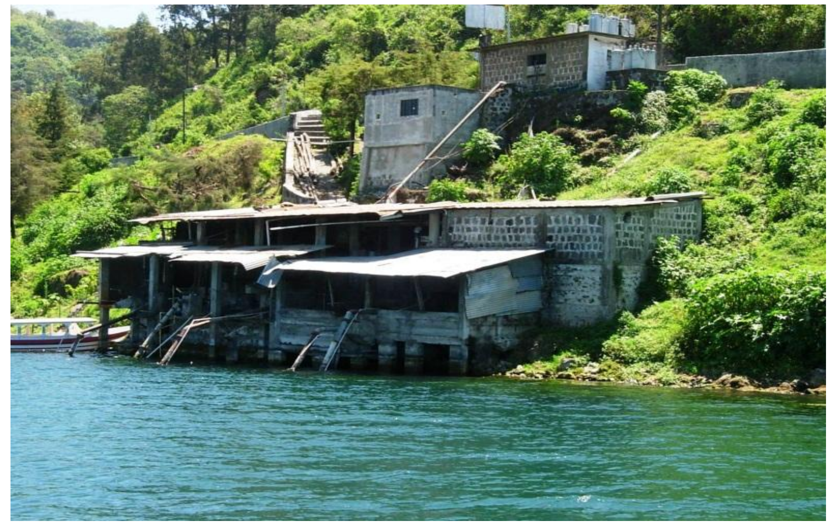


COBUSOT	AREA (ha)	Porcentaje (%)
Granos básicos	11,375	27.29
Bosque mixto	6,759	16.22
Café	6,245	14.98
Arbustos - matorrales	5,269	12.64
Bosque conífero	4,316	10.35
Bosque latifoliado	3,219	7.72
Pastos naturales y/o yerbazal	2,529	6.07
Centros poblados	822	1.97
Hortaliza - ornamental	633	1.52
Mosaico de cultivos	176	0.42
Lago - laguna	172	0.41
Playa y/o arena	115	0.28
Aguacate	36	0.09
Arena y/o material piroclástico	34	0.08
Total	**41,700**	**100.00**

Principal threats

- Hábitat degradation, both terrestrial and aquatic
- Loss of forest cover
- Water contamination
- Vulnerable to extreme events

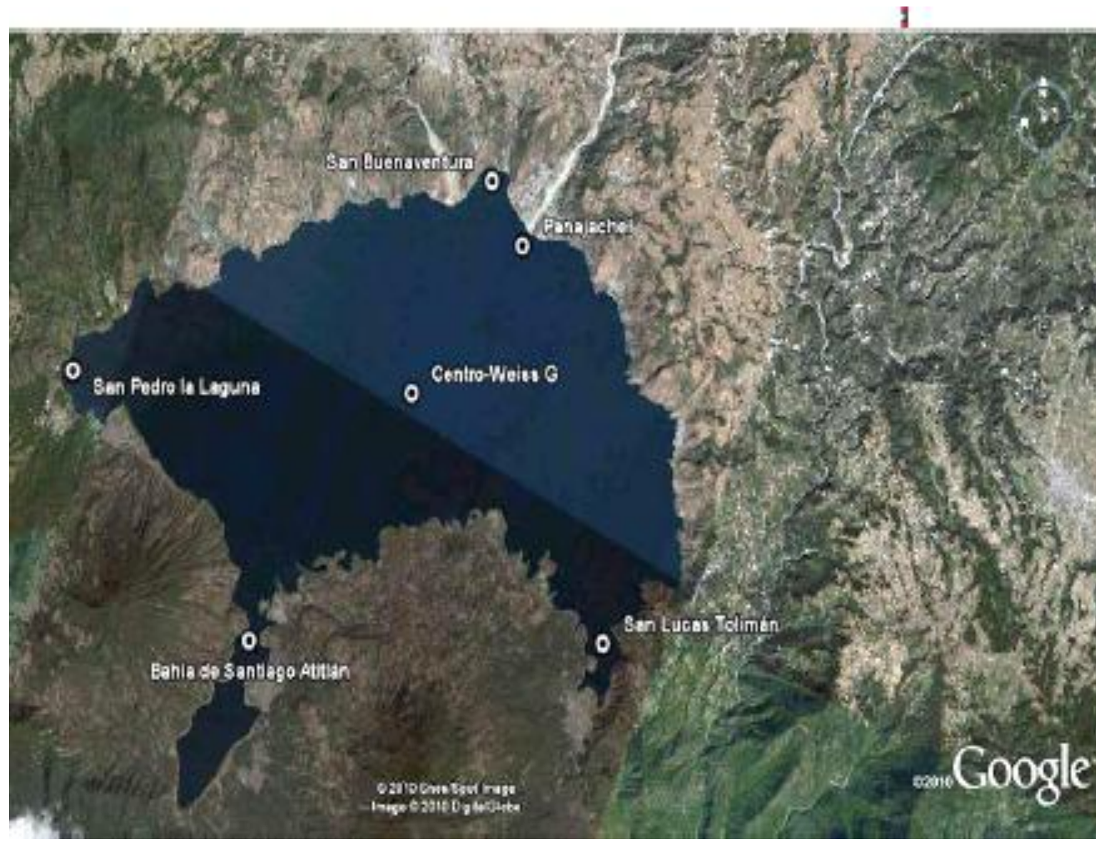
Why is Lake Atitan important?



- Central America's largest lake
- Largest drinking water source
- Source of fish and material for local crafts
- Basis for tourism Industry
- Recreation
- Archeological sites
- Sacred site for Mayans

Drinking Water

- Directly from lake
- Panajachel 40%
- San Lucas Tolimán 95%
- Santiago Atitlán 55%
- San Pedro la Laguna 85%
- Rest from springs and mountain streams.
- Some but not all is treated



Courtesy of Lake Atitlan NGO

Physical Aspects of the Lake

Form and shape promote, wind and gyres

Daily wind (chocomil) produces strong wave action, 11 am- 11 pm

Events that have altered Lake Atitlan

1960's- Introduction of black bass- the elimination of the endemic Giant Atitlan grebe

Volcanic activity- drop of lake level by 3.5+ meters - altering littoral zone (reeds, wetland buffers, grebe conservation)

Events that have altered Lake Atitlan

2005, 2010- Hurricanes Stan and Agatha result in mass wasting of the watershed

Hurricane Agatha destroyed the waste water treatment plant in Panajachel

Atmospheric loading of pollution, crop burning and vehicles?

Events that have altered Lake Atitlan

1970's to present- pumping of untreated and treated sewage water into the lake

Events that have altered Lake Atitlan

Dec 2008- 1st cyanobacteria bloom recorded

Oct 2009- 2nd, more sustained cyanobacteria bloom

April 2010- development of *Microcystis* in the metalimnion

June-July 2010- development of a small bloom prior to lake mixing

July 2011, minor , sort duration bloom

May 23 2012, bloom

(Brezonik and Fox 1974, Rejmankova et al 2011, Dix unpublished, Chandra, unpublished)

Events that have altered Lake Atitlan

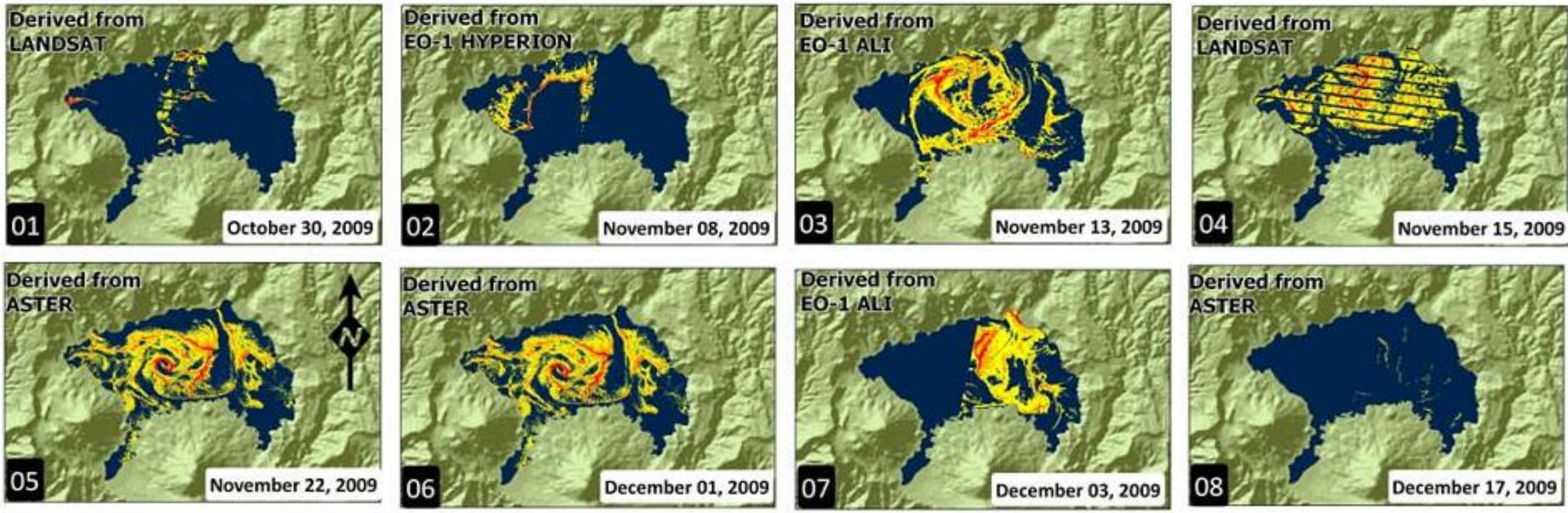
No historical algal blooms

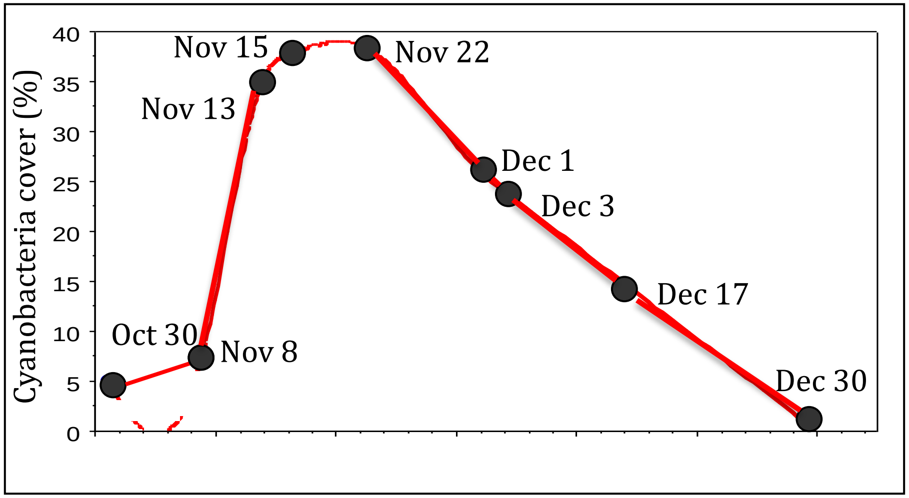
1976- epilimentic waters- <10% of *Microcystis in* total cell counts

1983 & other snapshot studies- >50% *Microcystis*

Interviews with fisherman suggest that past generations have observed blooms, When?

Understanding of bloom dynamics & nutrient limitation- 2009 satellite data





SERVIR NASA USAID CATHALAC GEO

Image Credit:
CATHALAC/NASA/USAID

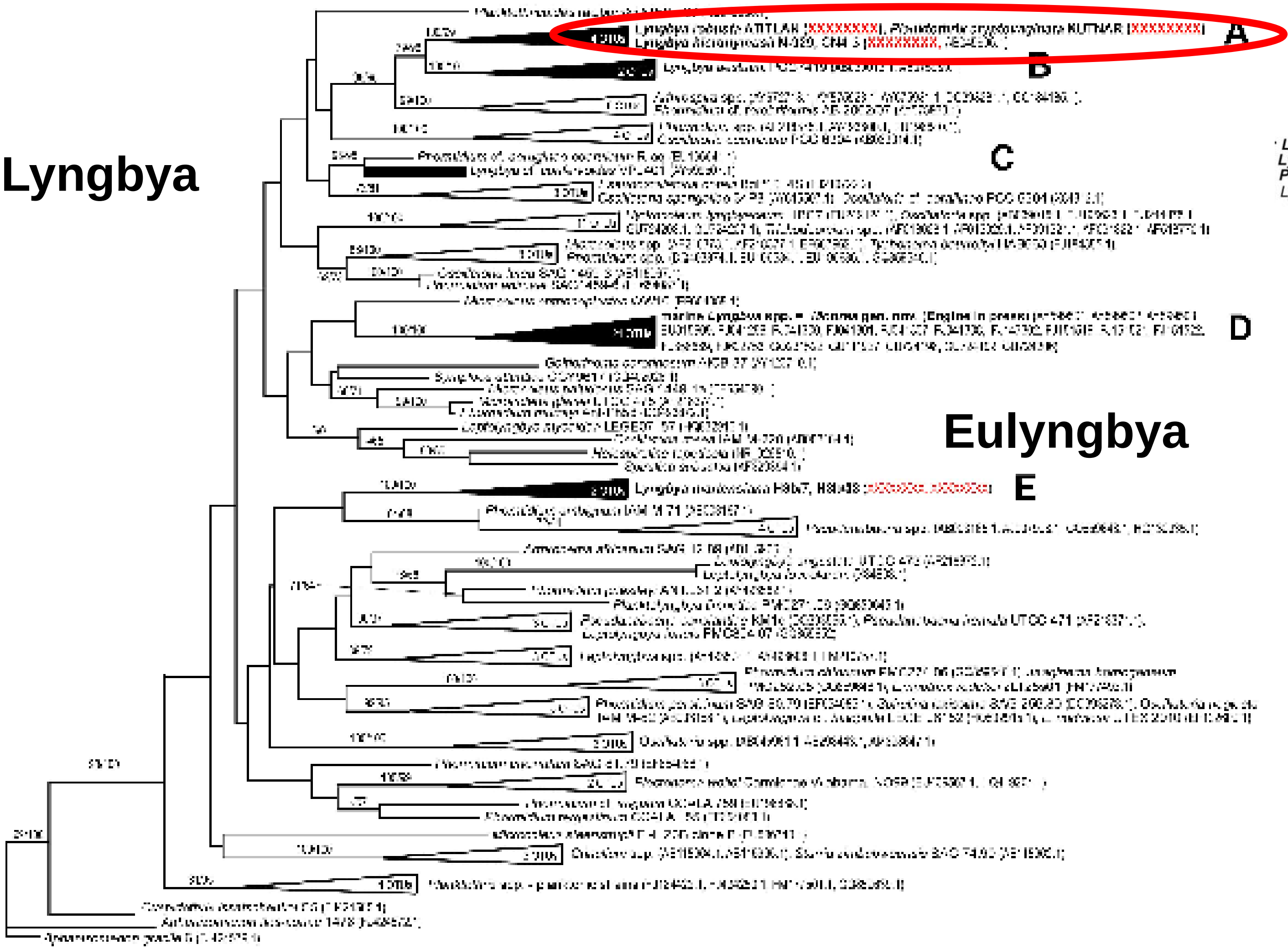

Algae bloom 2008-2011
2008
2009
2010
2011
2012
Lyngbya robusta (L. hieronymusii, var. robusta)

Nov 2008 and October 2009 blooms identified as *Lyngbya robusta ATITLAN*

April 2010 (dry season), development of *Microcystis cf. bortrys in low numbers in the metalimnion*

Blooms for *Lyngbya* robusta mostly recorded in Asian lakes

Phylogenetic analysis of the genus *Lyngbya* (16S rRNA gene sequencing)

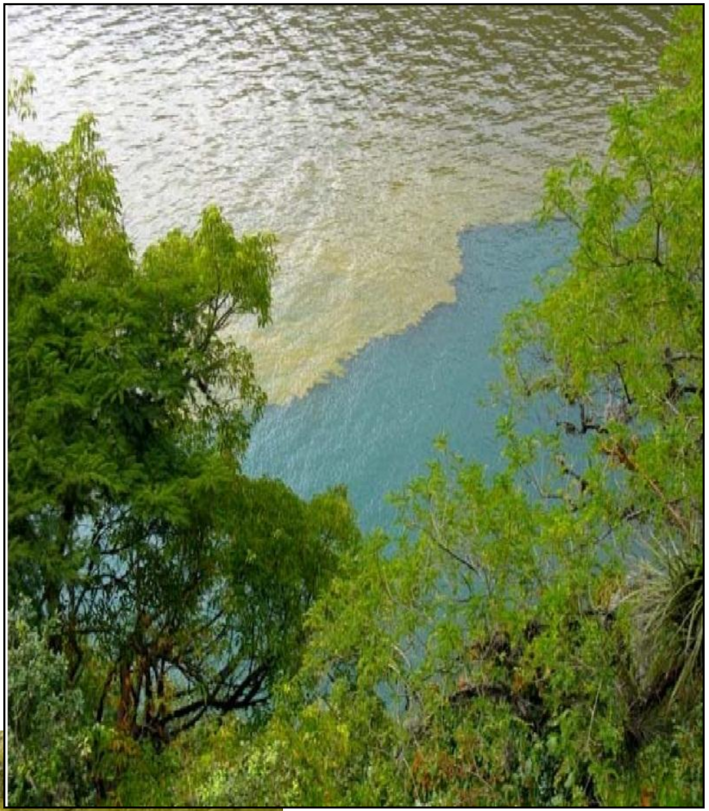


cluster A:

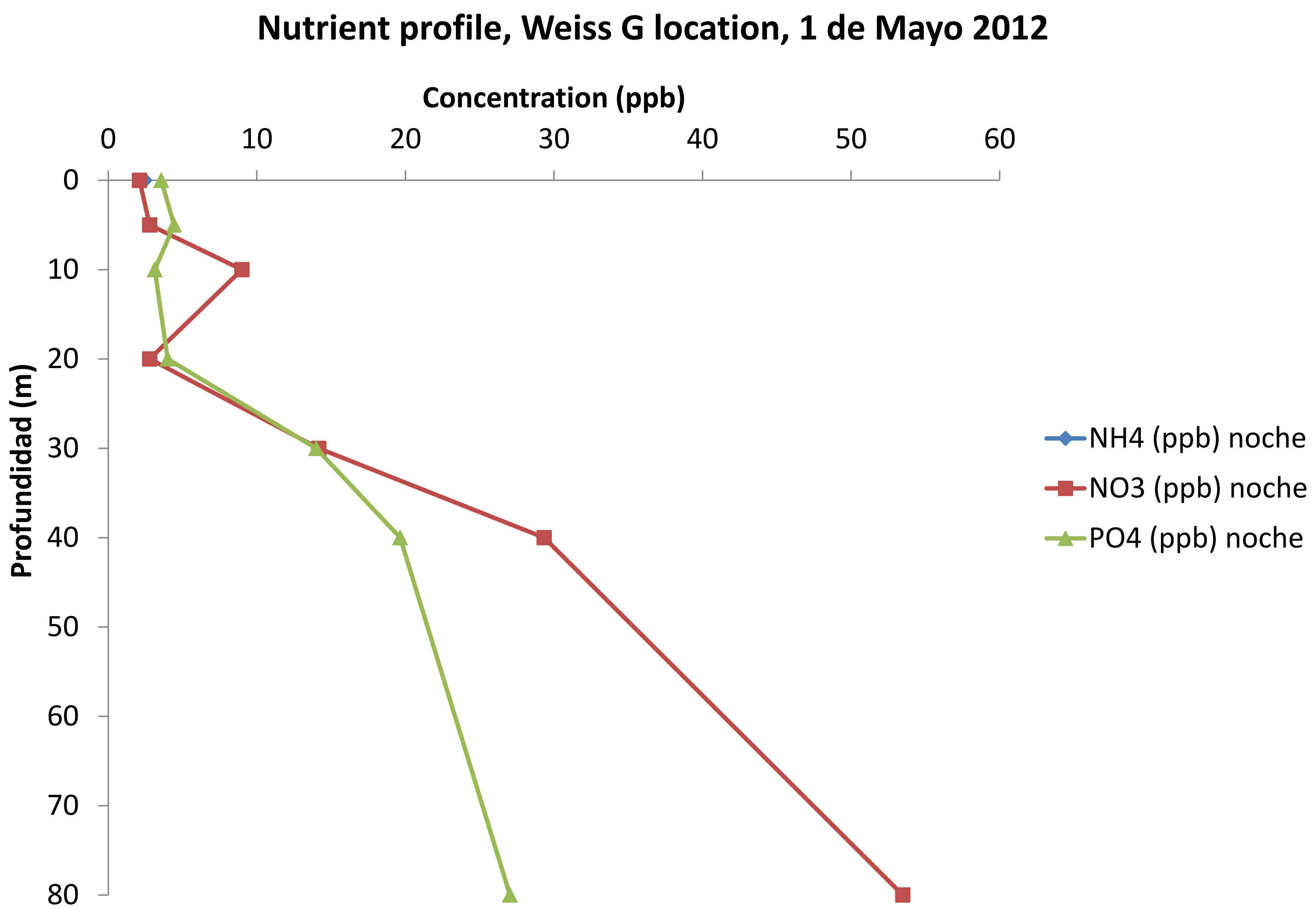
Lyngbya robusta **ATITLAN (XXXXXXXX)**
Lyngbya hieronymusii **N-929 (XXXXXXXX)**
Planktothrix cryptovaginata **KUTNAR (XXXXXXXX)**
Lyngbya hieronymusii var. *hieronymusii* CN4-3 (AB045906.1)

Komárek et al. In press

The first record of the planktic *Lyngbya* (*Limnoraphis*) in Guatemala is from September 1983 from the Lake Amatitlán, a large hypereutrophic lake near Guatemala City under the problematic name *Lyngbya birgei* (not published, in protocols WHO).

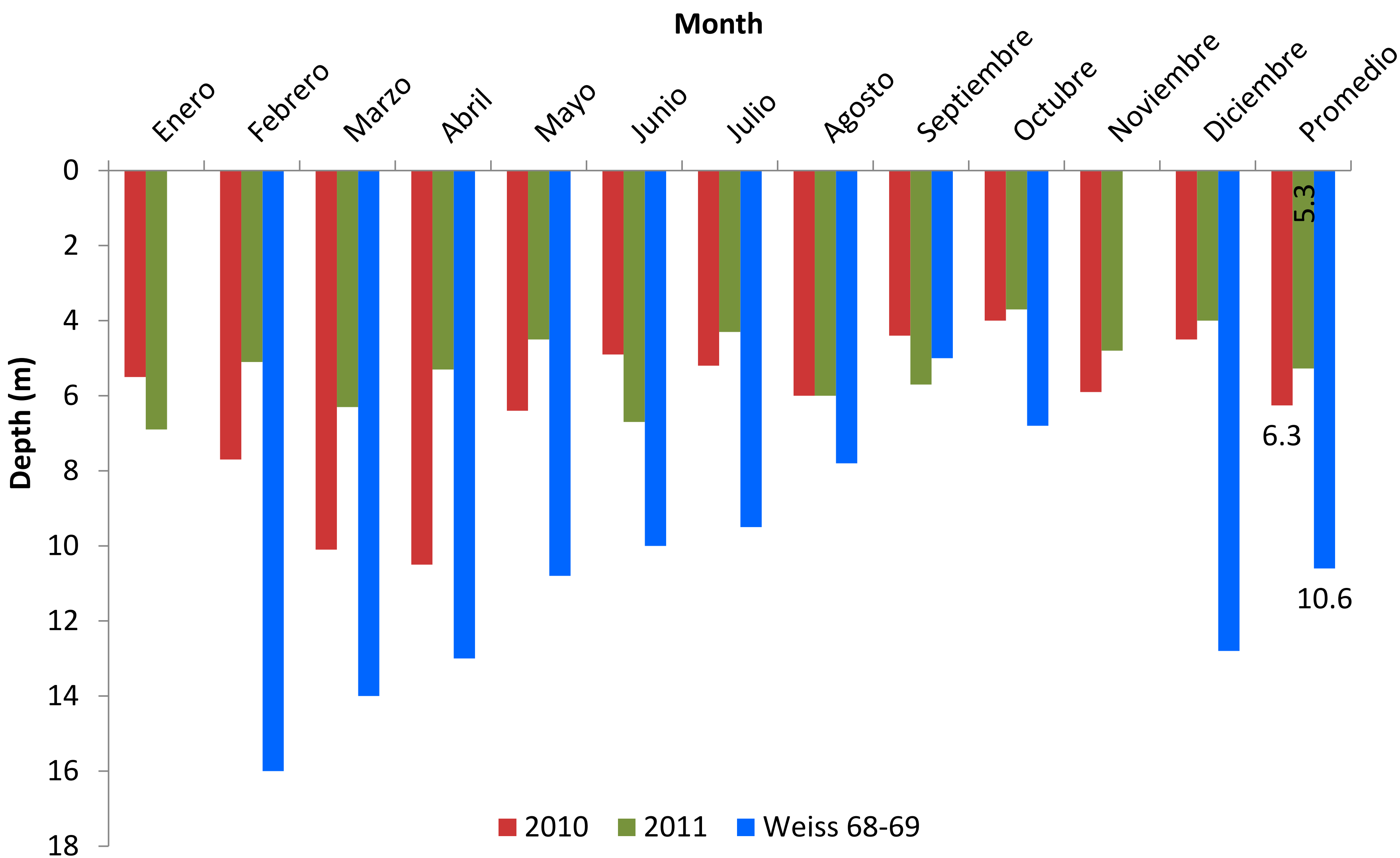


Students sampling for water quality profiles, nutrient limitation bioassays, and benthic invertebrate surveys

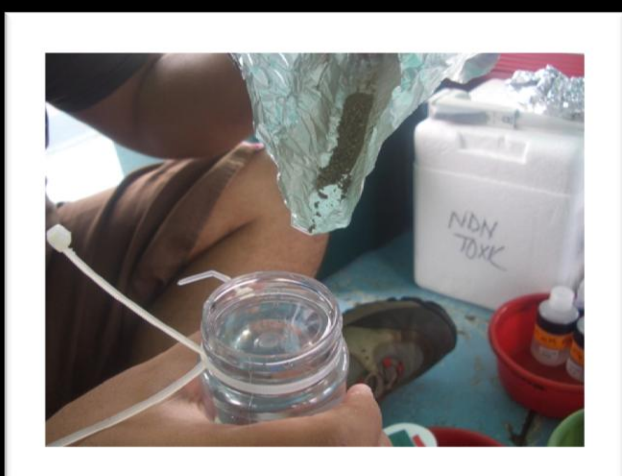


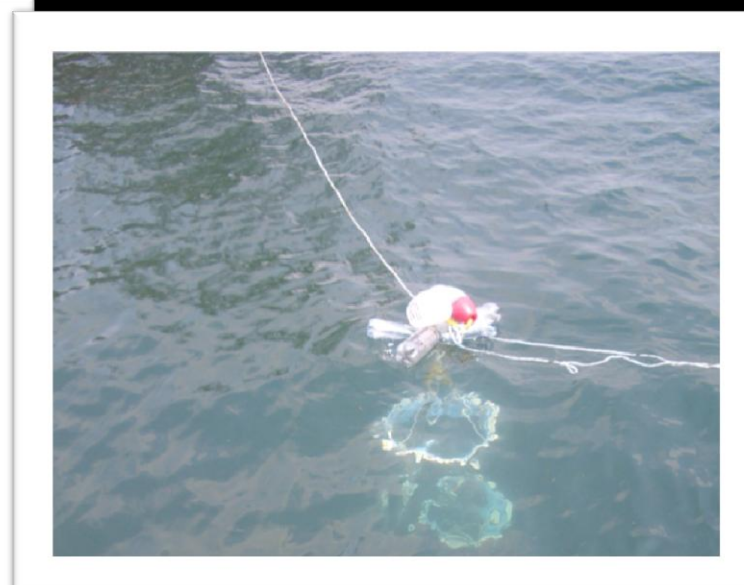
Nutrient profile, Weiss G location, 1 de Mayo 2012
Concentration (ppb)
0
10
20
30
40
50
60
Profundidad (m)
0
10
20
30
40
50
60
70
80
NH4 (ppb) noche
NO3 (ppb) noche
PO4 (ppb) noche

Working to develop a monitoring program for clarity and historical comparison

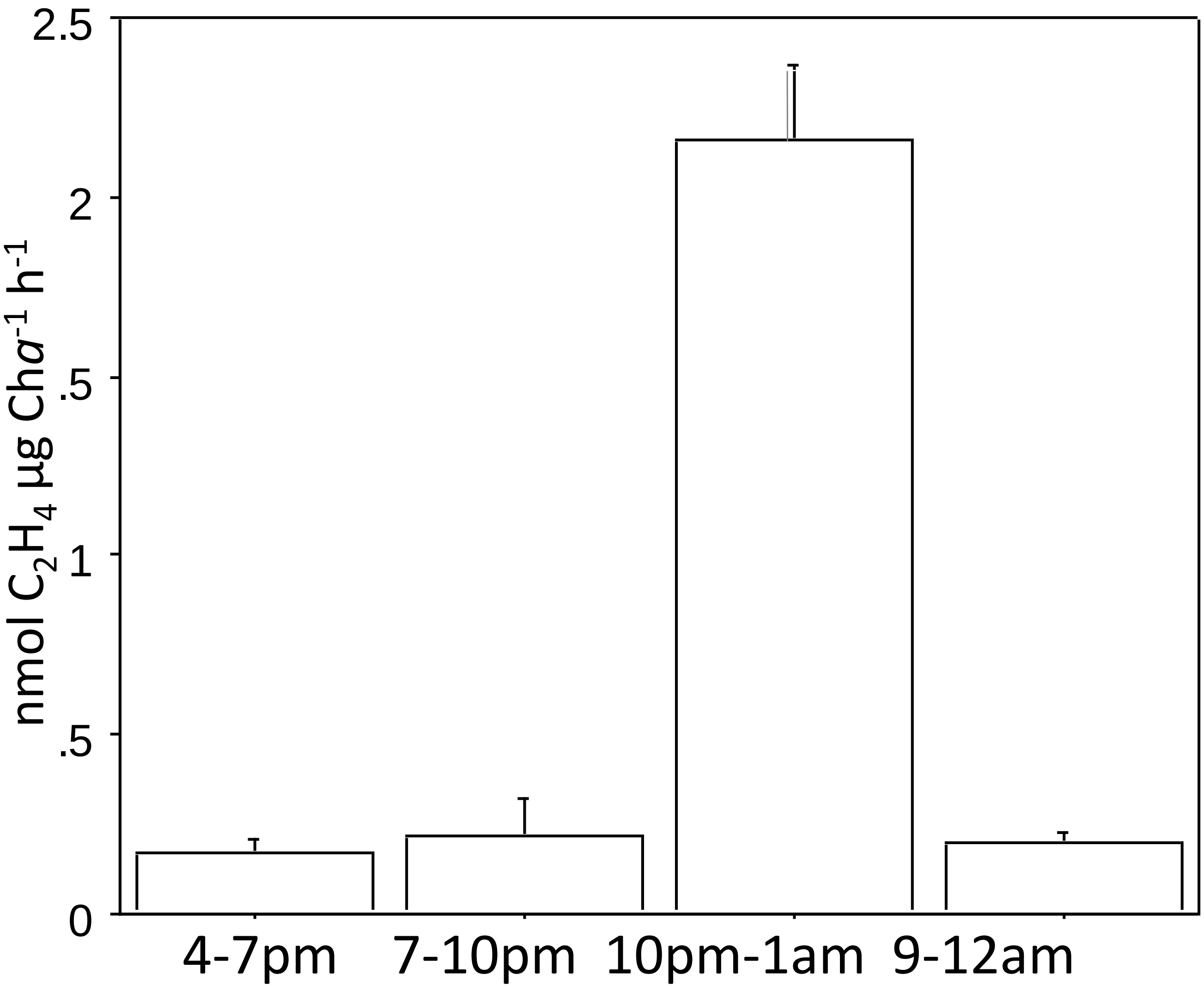


Students conducting bioassays for phytoplankton and microbial nutrient limitation

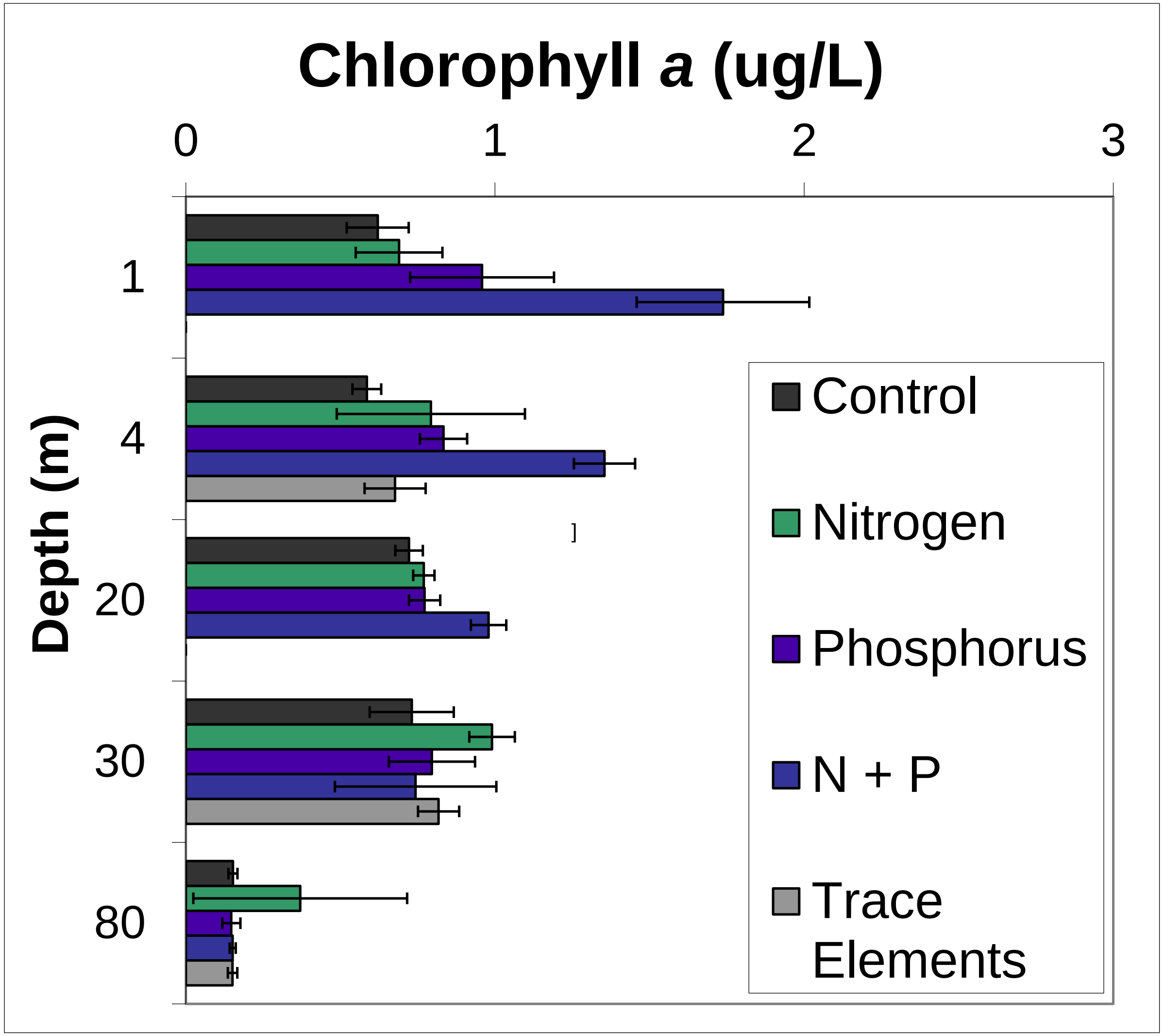




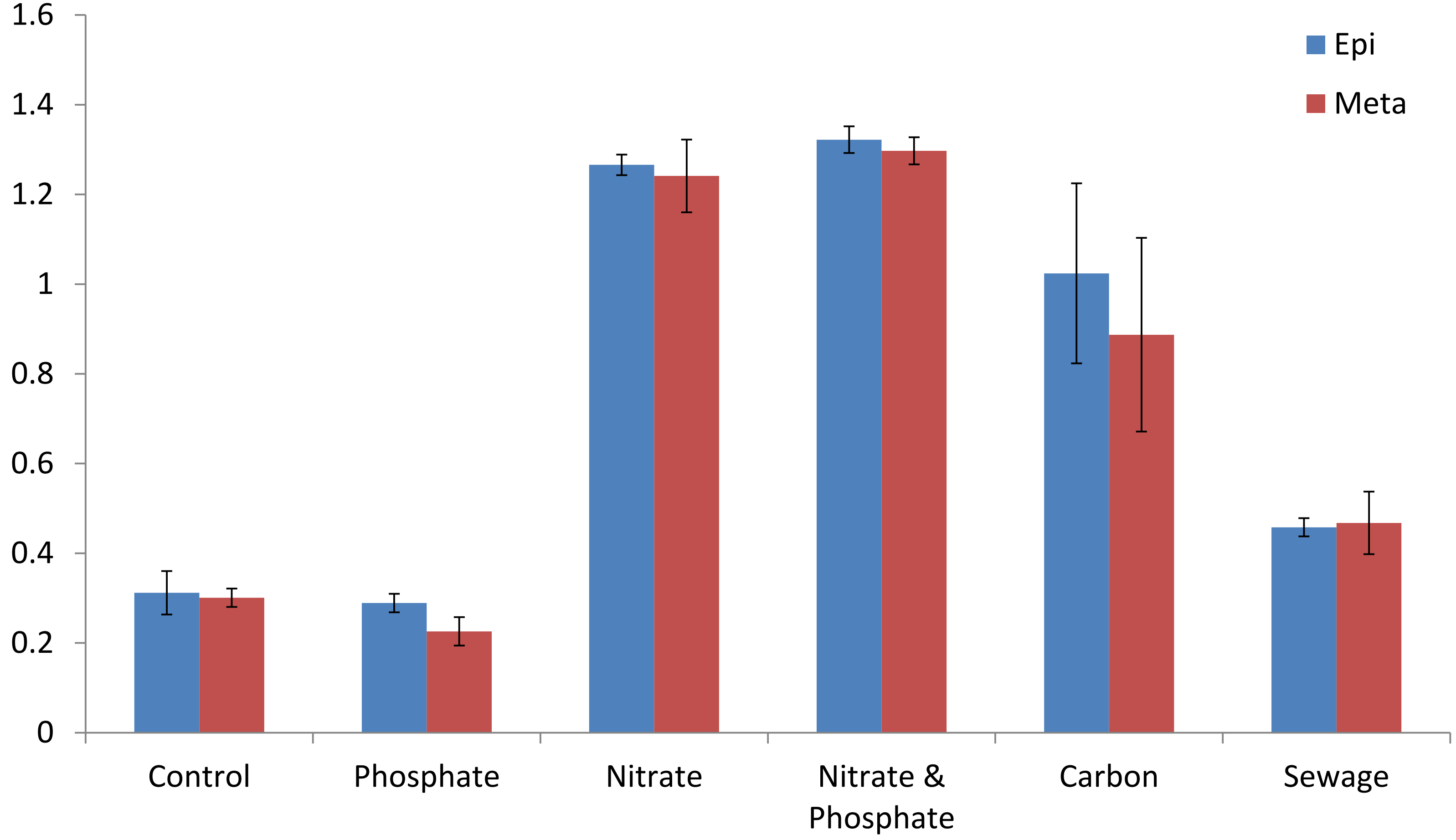
Nitrogenase activity- active N-fixation during the bloom at night time at a similar rate to a related marine species



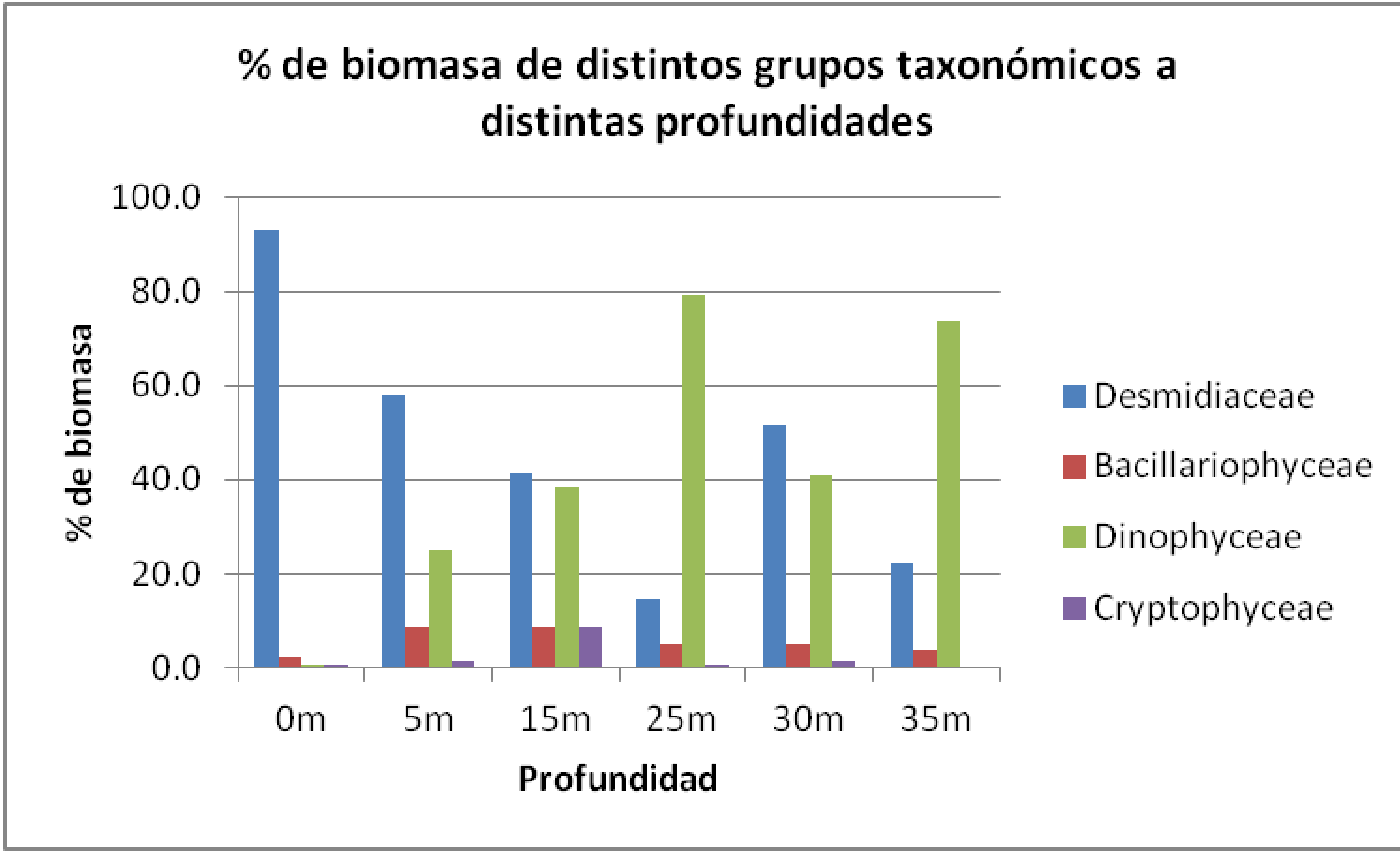
Nutrient limitation at the end of dry season indicates co limitation in the epi & metalmnions, no trace element limitation



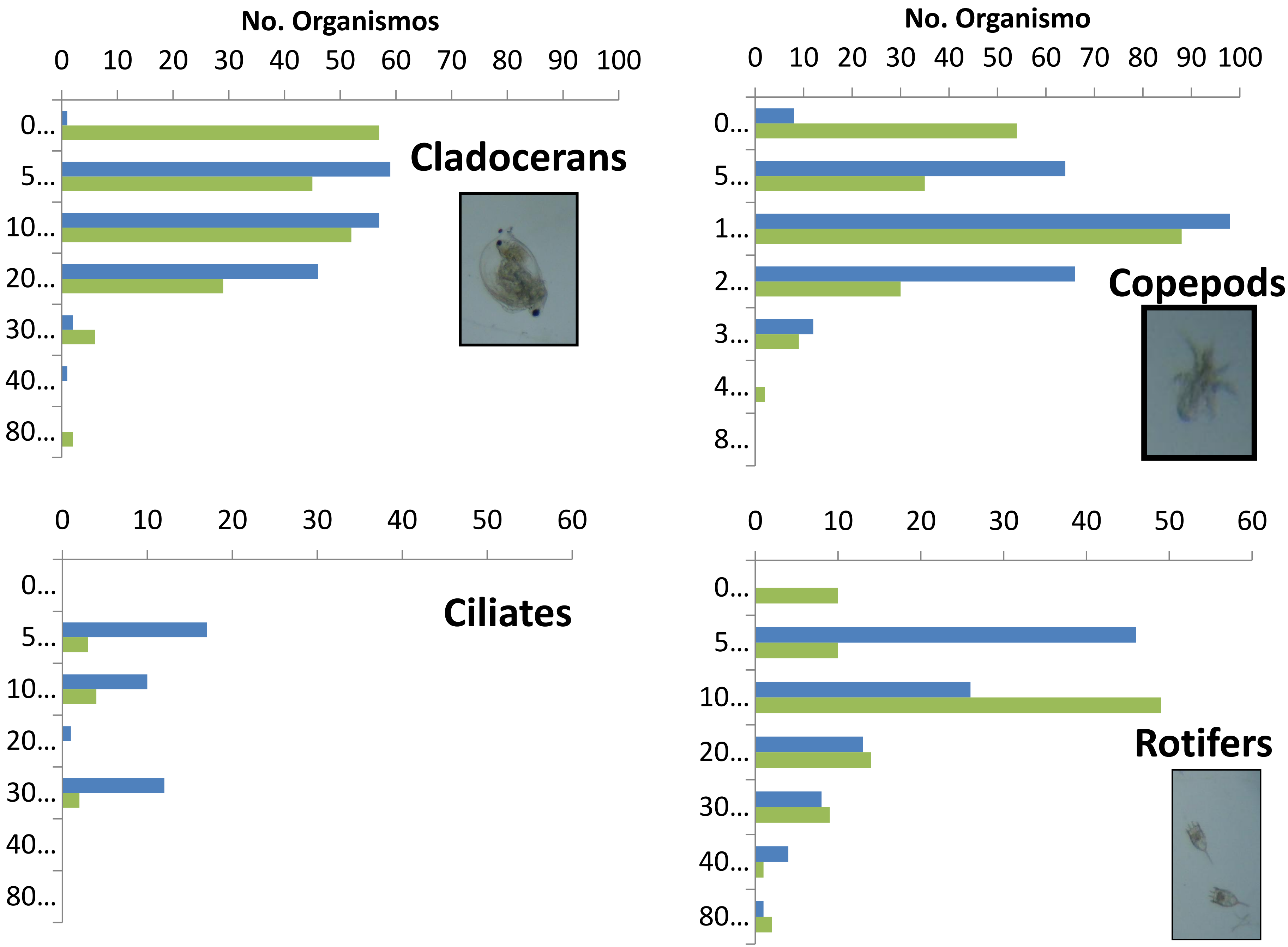
Heterotrophic bacteria N, colimited during dry season



Phytoplankton distribution at depth



What is in the lake? Zooplankton classification and diel migration

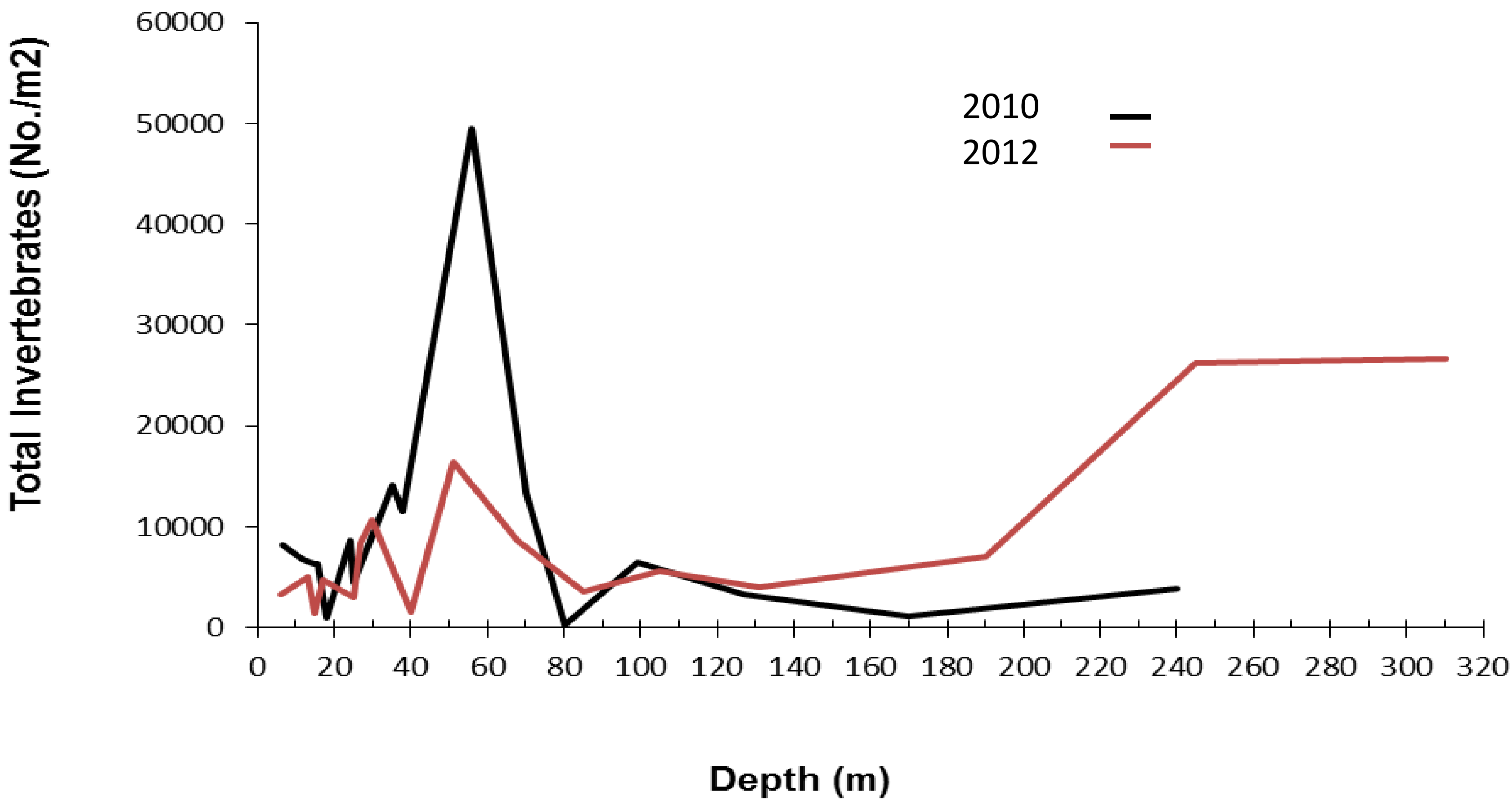

No. Organismos
0 10 20 30 40 50 60 70 80 90 100
0…
5…
10…
20…
30…
40…
80…
Cladocerans
No. Organismo
0 10 20 30 40 50 60 70 80 90 100
0…
5…
1…
2…
3…
4…
8…
Copepods
0 10 20 30 40 50 60
0…
5…
10…
20…
30…
40…
80…
Ciliates
0 10 20 30 40 50 60
0…
5…
10…
20…
30…
40…
80…
Rotifers



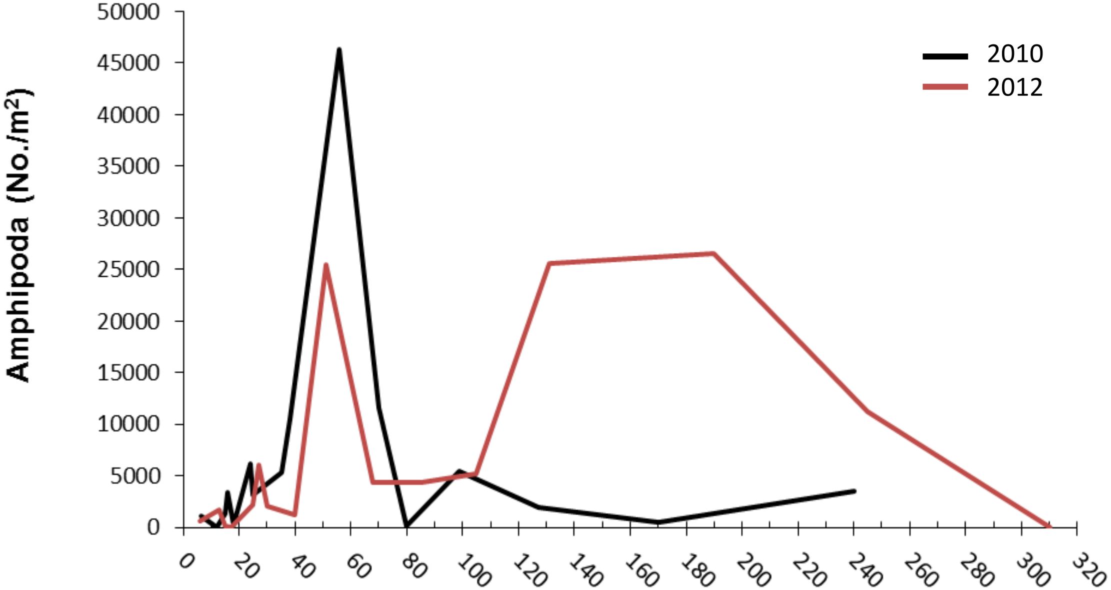




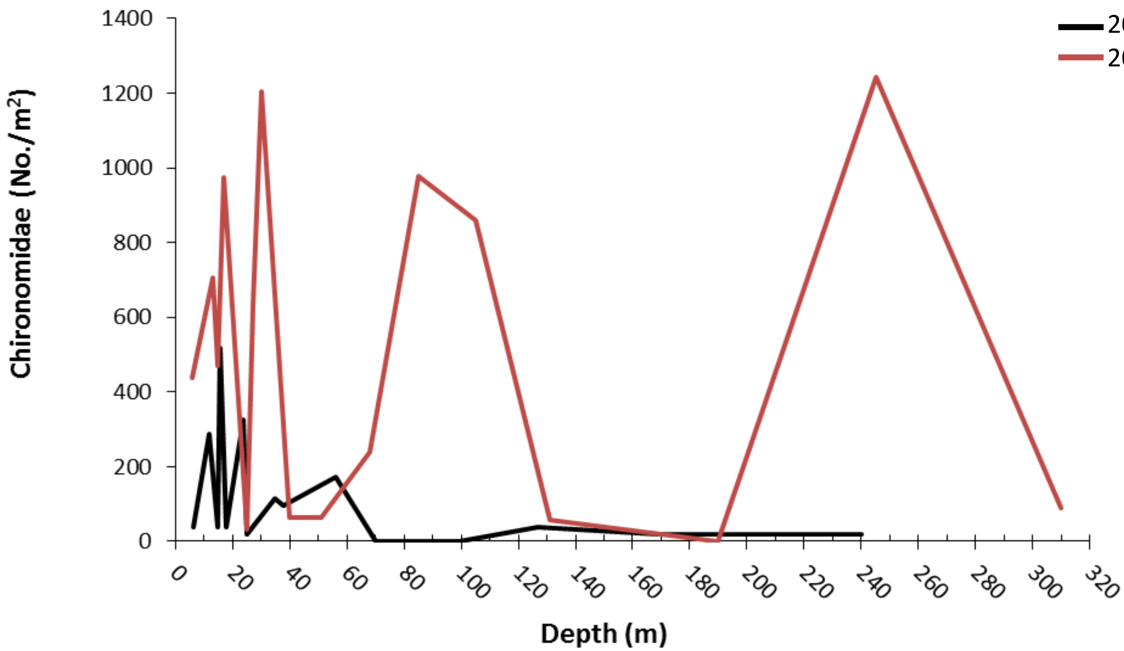
0774
UNR



Indices	2010	2012
Shannon-Wiener	1.066	0.8862
Simpson	0.485	0.4265
Dominance	0.515	0.5735



Amphipoda (No./m²)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320
2010
2012



Chironomidae (No./m²)
1400
1200
1000
800
600
400
200
0
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320
Depth (m)
2010
2012

IMPACTS OF CYANOBACTERIAL BLOOMS

- Health Problems, documentation is not complete
- Potential loss of fish as food, due to alert to stop eating fishes from the President’s office due to cyanotoxins
- Poor drinking water quality and associated increases in other bacteria (*E. coli*)
- Tourism reduction (50% during 2009 bloom)
- Income reduction, 25% unemployment

Cyanotoxin analysis from water indicates low to no toxin concentrations of concern

CYANOTOXIN	Nov-09 DRY SEASON Bloom *Lyngbya*	April-10 DRY SEASON No Bloom *Lyngbya, Microcystis present*	June-10 WET SEASON No Bloom
Cylindrospermopsin***	12*	---**	---**
Saxitoxin***	58*	---**	---**
Aplysiatoxins***	*Non Detect*	---**	---**
Lyngbyatoxin-a***	*Non Detect*	---**	---**
Debromoaplysiatoxin***	*Non Detect*	---**	---**
Microcystin	*Non Detect*	*Non Detect*	---**
Anatoxin-a	*Non Detect*	---**	---**

** Lower than Advisable Clean Up Standard*

*** Not tested due to low or no applicable species counted*

**** Lyngbya originated toxins*

Roegner et al. 2011

Lake Management

- AMSCLAE, government entity charge with management of lake and watershed.
- RUMCLA, Multiple use protected area for Atitlán and its watershed.
- National Forestry Institute
- Departmental, municipal and community development councils
- Ministry of Agriculture (gives farmers free 20:20:20 fertilizer)
- Conflicts related to management authority

Management needs

- Reduction of N and P input (wastewater runs directly into lake for the most part), currently no tertiary treatment: very narrow shore zone.
- Agricultural extension to improve efficiency of fertilizer use
- Run off and erosion control.
- Solid waste control.
- Shoreline stabilization .
- Urban development control.
- Science based efforts to manage the lake, don’t take Lake Tahoe system for granted

Wastewater

- Construction of traditional wastewater treatment plants until money ran out, planned in same areas where they blew out from Stan and Agatha
- Initiatives to build artificial wetlands, some unsuccessful, we are setting up other pilot projects with local landowners and local groups (e.g. *Eichornia*)

Class of 2010

2010 participants
April (n=36), June (n=14), July to Aug (n=5) training at Castle Lake Station USA

Training in basic limnological methods and watershed surveys, discussions on governance structures

Class of 2012

2012 participants
April
Theoretical trainings in Guatemala City (n=38),

Field trainings n=14
July to Aug (n=5) trainings will start at Castle Lake Station USA

Training in basic limnological methods and watershed surveys, discussions on governance structures


JARDIM
BOTÂNICO